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MEASUREMENT OF THE VERTICAL GRADIENT OF THE SEMIDIURNAL TIDAL WIND PHASE IN WINTER AT THE 95 KM LEVEL

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ABSTRACT

When supplemented by absolute reflection height measurements, low frequency wind measurements in the 90-100 km height range become truly competitive in comparison with the more widely used radar meteor wind observations. For example, height profiles of the wind parameters in the so-called meteor zone can be obtained due to the considerable interdiurnal variability of the average nighttime reflection heights controlled by geomagnetic activity.

The phase of the semidiurnal tidal wind is particularly height-dependent. The measured vertical gradient of 1/4 h/km in winter corresponds to a vertical wavelength of about 50 km.

Wind measurements in the upper atmosphere, at heights between 90 and 100 km, have been carried out at the Collm Geophysical Observatory of Karl Marx University Leipzig for a number of years now. These measurements use the closely-spaced receiver method and three measuring paths, on 179, 227, and 272 kHz. They take place every day between sunset and sunrise, i.e., nightly. A night in this sense may last as long as 18 hours in winter. Both the measurements and their evaluation are completely automatic, and the prevailing winds and tides are separated.

This technique has a number of advantages which, apart from being able to assign wind readings to accurate heights, could be described as follows:

(1) Daily measurements can be made over longer periods with comparatively simple equipment and give very good information at low cost.

(2) Wind measurements are possible on several measuring paths from one point. This gives representative data on the average wind conditions over large areas such as Central Europe, from one observatory. The transmitters are broadcasting stations which can be used free of charge over decades and whose operation is guaranteed by governments. That means we need no powerful transmitters of our own, and interference is avoided.

(3) Wind variations with very short periods can be studied because of the high measuring density of one reading per minute and measuring path, or even more. For example, the average in 1982 was 1.7 reading per minute on 272 kHz; eight readings per minute are possible over shorter periods of time.

(4) The zonal and meridional wind components can be measured at the same time and in the same volume in the upper atmosphere.

(5) The wind records are available on-line. Automatically operated equipments allow the parameters of circulation to be provided with a time delay that is determined and limited only by the period of tidal winds and which is acceptable for a synoptic meteorology of the upper atmosphere; and

(6) The whole arrangement lends itself to mobile use easily, so that an entire measuring network could be standardized on this basis.

Problems have so far been encountered in determining the reference height since these are not pulse measurements at vertical incidence but measurements on continuous-wave transmitters at oblique incidence. It was possible to calculate the reflection height from the electron density profiles only in the past, and there was no way to determine interdiurnal or short-time height variations. This handicap was overcome last year with the help of a new method developed by Kurschner at our observatory. The absolute value of the reflection height is obtained from the time delay between the sky wave and the ground wave transmission of respective modulation bursts in the frequency range around 1,600 Hz, and this is presently done on the 179 kHz measuring path. Beyond our application, the method could be used in all cases where ionospheric research is conducted with the aid of the sky wave component from l. f. broadcasting transmitters. One example is A3 absorption measurements.

When l. f. ionospheric drift measurements are supplemented in this manner they become competitive with the radar meteor wind method, and this all the more since the advantages of the latter are hardly used to the full in any field. The only disadvantage of the method is that l. f. drift measurements are restricted to the night hours so that problems arise in determining the diurnal tidal wind component which is, however, small anyway in medium and higher latitudes.

To give an example of the results that can be obtained with this method, we would like to present our wind measurements of December 1982 and January 1983 and draw a few conclusions. The transmitter distance is 170 km for the 179 kHz measuring path, 460 km for 227 kHz, and 400 km for 272 kHz. The reflection points are over Central Europe near 52°N and 15°E and are about 200 km apart at a height range between 90 and 100 km. The average integral measuring density was more than 3 values per minute.

Figure 1 shows the results of the wind measurements for an individual night in December 1982, at the top for the zonal component, below for the meridional component. The mean nighttime reflection height is 90 km. The table gives a survey of the results obtained from the harmonic analysis of the wind records for each night during the two months, using the averages from all three measuring paths. As it is seen, the zonal prevailing wind is mostly directed toward the east, and the meridional prevailing wind toward the south. Even a cursory look at the table shows that there is a close connection between the phase position of the semidiurnal tidal wind and the measured height — great heights are equivalent to an early phase, and vice versa.

Figure 2 shows the average daily wind variation at two average height levels of 90 and 100 km for December 1982. The wind and height values have been arranged hourly, in two groups below and above 94.5 km. We can see a clear phase difference in the semidiurnal tidal wind which is somewhat above two hours for a height difference of 10 km.

Using the analyses for individual days from the table, one can calculate exact regression lines. An example would be this particular phase of the semidiurnal tidal wind. Figure 3 shows the regression lines for all three measuring paths for the zonal component only, and for the average from all three paths, in the latter case for the zonal and meridional components. The vertical gradient of the phase results from the slope of the regression line on 179 kHz and is a quarter-hour per kilometer, or 7°/km. This is equivalent to a vertical wavelength of about 50 km.

The slope seems to fall off slightly as the equivalent frequency is reduced. This apparent reduction results from the fact that the absolute heights are only measured on 179 kHz and the reflection height variations are smaller for a steeper N(h') profile and lower equivalent frequencies. The

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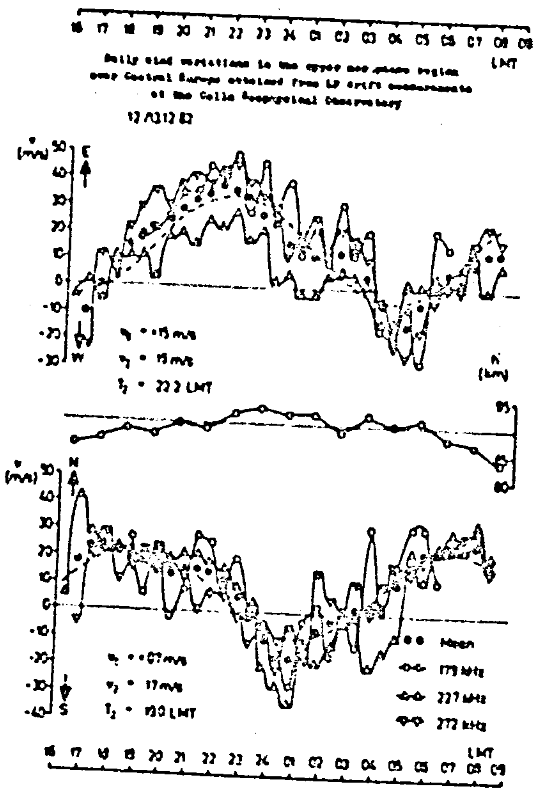

Figure 1. Daily wind variations in the upper mesopause region over Central Europe obtained from LF drift measurements at the Collm Geophysical Observatory.

equivalent frequency is 140 kHz for the 179 kHz measuring path, 115 kHz for the 272 kHz measuring path and 70 kHz for the 227 kHz measuring path.

It is typical for values of the vertical gradient of the phase of the semi-diurnal tidal wind to be in the range of a quarter-hour per kilometer, and such values are found even where the usable height range increases upward in the presence of magnetic storms. The reflection heights depend largely on geomagnetic activity. To calculate a regression line we used the sum of the K_1 values for the six three-hour intervals from 15 to 9 hours UT. It turned out that in the range from K_1 =10 to K_1 = 30 the height increases by a half kilometer for each unit that is added to the sum of K_1.

During stratospheric warming effects in the upper mesopause region when the prevailing zonal wind direction is reversed, the vertical gradient of the phase of the semidiurnal tidal wind is also 15 min/km, but the sign is quite opposite: the phase is shifting from the evening to midnight hours with increasing reflection height, just now observed during the last event in February 1983.

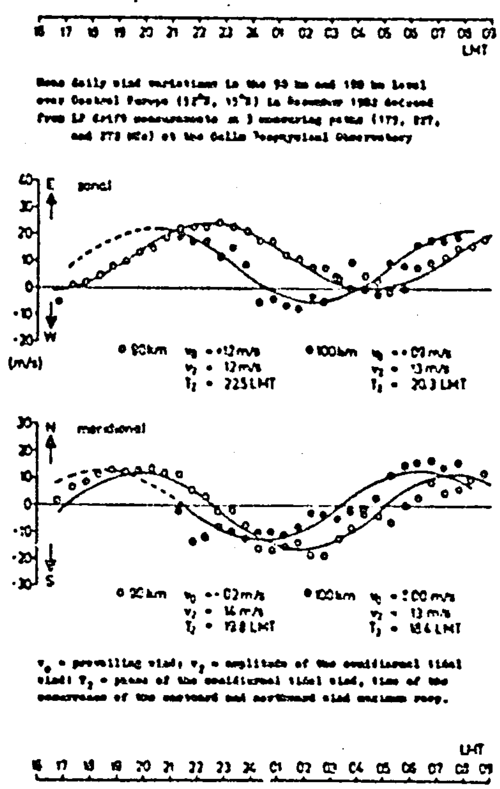

Figure 2. Mean daily wind variations in the 90 km and 100 km level over Central Europe (52°N, 15°E) in December 1982 deduced from LF drift measurements on 3 measuring paths (179, 227, and 272 kHz) at the Collm Geophysical Observatory. v_0 – prevailing wind; v_2 – amplitude of the semidiurnal tidal wind; T_2 – phase of the semidiurnal tidal wind, time of the occurrence of the eastward and northward wind maximum, respectively.

Table 1. Results of upper atmosphere wind measurements over Central Europe obtained from LF drift measurements on 179, 227, and 272 kHz at the Collm Geophysical Observatory.

Night	December 1982 zonal v_0	v_2	T_2	meridional v_0	v_2	T_2	h'	January 1983 zonal v_0	v_2	T_2	meridional v_0	v_2	T_2	h'
01./02.	+16	08	22.6	+12	10	19.2	90	+15	18	22.2	-09	18	19.2	92
02./03.	+06	16	21.8	+06	17	19.3	91	+14	13	23.4	-08	10	17.6	92
03./04.	+11	19	20.0	-09	22	18.9	96	+08	09	19.8	-12	10	18.4	93
04./05.	+32	20	18.7	+04	14	16.7	107	+06	23	21.2	-03	23	18.6	94
05./06.	+07	22	20.3	-01	20	18.5	95	+07	13	22.1	-10	14	20.1	92
06./07.	+06	15	21.6	-09	18	19.2	95	+05	19	21.8	-07	13	19.6	89
07./08.	+03	25	19.2	00	17	17.9	103	+08	25	22.2	-03	18	19.2	83
08./09.	+09	15	20.2	+06	10	17.4	104	+13	15	21.3	-05	18	18.4	95
09./10.	-07	18	22.8	-02	13	21.2	93	+12	12	20.1	-01	10	17.6	103
10./11.	00	20	21.1	+03	10	18.8	100	+20	05	17.8	+01	02	16.6	102
11./12.	+11	17	21.0	-05	20	19.3	96	+20	07	21.2	-06	14	19.4	93
12./13.	+15	19	22.2	+07	17	19.0	93	+11	21	21.5	+01	22	19.1	92
13./14.	+23	10	00.5	+10	09	22.5	88	+10	21	22.0	-07	20	19.9	94
14./15.	+09	17	22.7	-06	12	22.2	89	+03	16	23.9	-04	13	19.1	94
15./16.	+16	06	20.9	-02	11	16.9	90	+07	23	20.8	-03	21	17.1	C
16./17.	+13	04	19.8	00	10	18.9	99	-03	22	21.0	-16	16	17.2	95
17./18.	+09	15	20.4	-07	15	19.7	96	+04	14	20.4	-06	10	18.5	97
18./19.	+08	18	21.0	-03	17	19.1	93	00	21	23.0	00	10	18.0	101
19./20.	+04	14	22.9	00	13	20.6	93	+02	20	23.6	-08	09	18.0	100
20./21.	+12	13	22.7	+03	05	19.9	95	+22	14	21.6	-11	18	17.7	97
21./22.	+03	14	18.6	+10	06	18.5	97	+09	16	21.1	-17	15	18.8	91
22./23.	+17	08	23.5	+01	18	21.5	89	+01	19	22.1	-10	15	17.9	94
23./24.	+18	09	21.9	-07	16	23.7	89	-03	12	19.5	-06	10	18.8	95
24./25.	+14	16	23.1	-08	17	23.5	90	+07	28	21.0	-06	19	18.8	100
25./26.	+09	20	2[illegible].8	-09	15	23.1	91	+01	27	20.9	-02	12	19.4	99
26./27.	+13	13	22.1	+03	15	20.0	90	+06	16	22.5	+01	11	20.7	94
27./28.	+14	09	21.3	-09	14	18.7	93	+18	20	21.4	+09	14	20.3	92
28./29.	+11	11	00.3	-17	15	19.4	91	+18	12	22.4	+15	04	20.3	96
29./30.	+02	21	00.0	-06	15	20.5	93	+19	10	22.0	-02	13	20.4	91
30./31.	-01	27	22.5	-01	13	19.9	93	+15	13	23.8	-02	14	20.9	95
31./01.	-07	11	22.4	-11	06	15.3	93	+11	12	17.5	-02	12	17.8	100

Symbols

v_0(m/s) = prevailing wind, positive towards E and N resp.

v_2(m/s) = amplitude of the semidiurnal tidal wind

T_2(LMT) = phase of the semidiurnal tidal wind, defined as the time of the occurrence of the eastward and northward wind maximum resp.

h'(km) = height

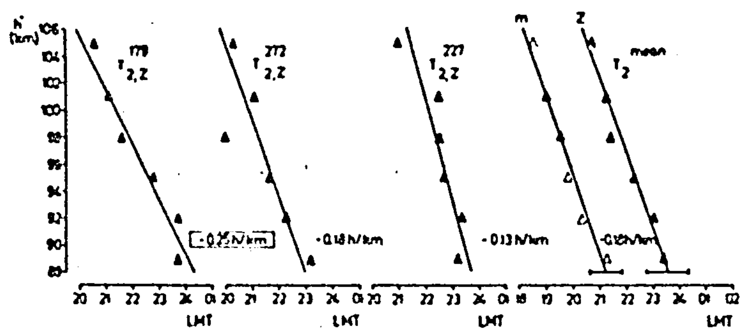

Figure 3. The vertical gradient of the phase T_2 of the semidiurnal tidal wind in December 1982 and January 1983 deduced from LF drift measurements on 3 measuring paths (179, 227, and 272 kHz) and from reflection height measurements on 179 kHz over Central Europe at the Collm Geophysical Observatory (z - zonal component, m - meridional component).

MEDIUM FREQUENCY RADAR OBSERVATIONS IN THE MIDDLE ATMOSPHERE

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ABSTRACT

In November 1982 the HEATING and the PRE (Partial Reflection Experiment) facilities near Tromso (Norway) were operated together in a pulsed mode as a radar system to investigate structures in the middle atmosphere. For the first time, echoes from the upper troposphere and stratosphere have been detected on a frequency of 2.75 MHz.

The paper will be published in full in: Journal of Atmospheric and Terrestrial Physics.